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Building a Sustainable Portfolio of Core Facilities: a Case Study

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Core facilities are an integral component of modern research institutions. Here, we describe our efforts over the past decade to build a sustainable portfolio of core facilities at Northwestern University. Through careful strategic planning, coordination, investment, and oversight, we have developed a model for managing core facilities that addresses researchers' needs within 3 schools across 2 campuses. Our management model is a partnership between core directors and central administrators that maintains operational control of each facility at the local level to ensure that the needs of researchers are being addressed. Central administrative oversight ensures that facilities are compliant with federal regulations, are financially sound, and align with institutional priorities. This hybrid management model is comprised of 4 pillars that are essential and necessary to ensure the long-term viability and success of facilities: core personnel, core space, institutional investment, and institutional evaluation. With these pillars in place, our facilities are well positioned to fulfill their key value propositions, to demonstrate a robust return on the university's investment, and to ensure that facilities remain vibrant, sustainable components of the research ecosystem for the foreseeable future.

Key Words: federal regulations, management model, pillars, return on investment

INTRODUCTION

Core facilities are an integral part of modern research universities and institutes.[1–4] They are specialized laboratories with unique (usually expensive) instruments and services, managed by scientists with the technical expertise and experience to help others who need these capabilities. They are operated as fee-for-service laboratories in which users pay for training, use of instruments, consulting, and specialized services. As users often pay using federal grants, core facilities are regulated by federal agencies and cannot serve as profit centers at nonprofit institutions.[5] Most facilities do not recover all of their operating costs through user fees, and so, home institutions are partners in the support and oversight of core facilities.

Core facilities are relatively new components of the research ecosystem.[2–4] They provide several unique value propositions for researchers and their institutions, including the following: *1*) a cost-effective means for making state-of-the-art instrumentation and services available to researchers, 2) enabling researchers to move their research programs in new directions by facilitating and supporting interdisciplinary strategies, *3*) serving as a nexus that encourages collaborations between internal and external researchers, thereby expanding the impact of research programs, and *4*) maximizing the institutional investment by sharing capacity with external researchers, when available. Commercial users pay higher fees, thereby contributing an important revenue source for facilities that help support their operations.[6]

In this article, we describe our efforts over the past decade to build a sustainable portfolio of core facilities at Northwestern University. We oversee 44 facilities located in 3 schools across 2 campuses spanning the physical sciences and engineering, biomedical, and clinical research programs (**Fig. 1**). Each campus has a different organizational structure and culture, and each discipline has unique needs and challenges. Through careful strategic planning, coordination, investment, and oversight, we have developed a management model that addresses these structural/cultural differences, needs, and challenges. Our model is a partnership among faculty, core directors, and central administrators that leverages their combined resources to meet the needs of researchers. The model has 4 pillars that are essential to ensuring the long-term viability and success of facilities: core personnel, core space, institutional investment, and institutional evaluation (**Fig. 2**). In this report, we

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Abbreviations: AVPR=associate vice president for research, CF=core facility, CFA=core facilities administration, FASEB=Federation of American Societies for Experimental Biology, FY=fiscal year, NUcore=centralized ordering system for all shared facilities at Northwestern University, OR=Office for Research, PI=principal investigator, ReLODE=Research Loan for Old and Duplicative Equipment, ROI=return on investment

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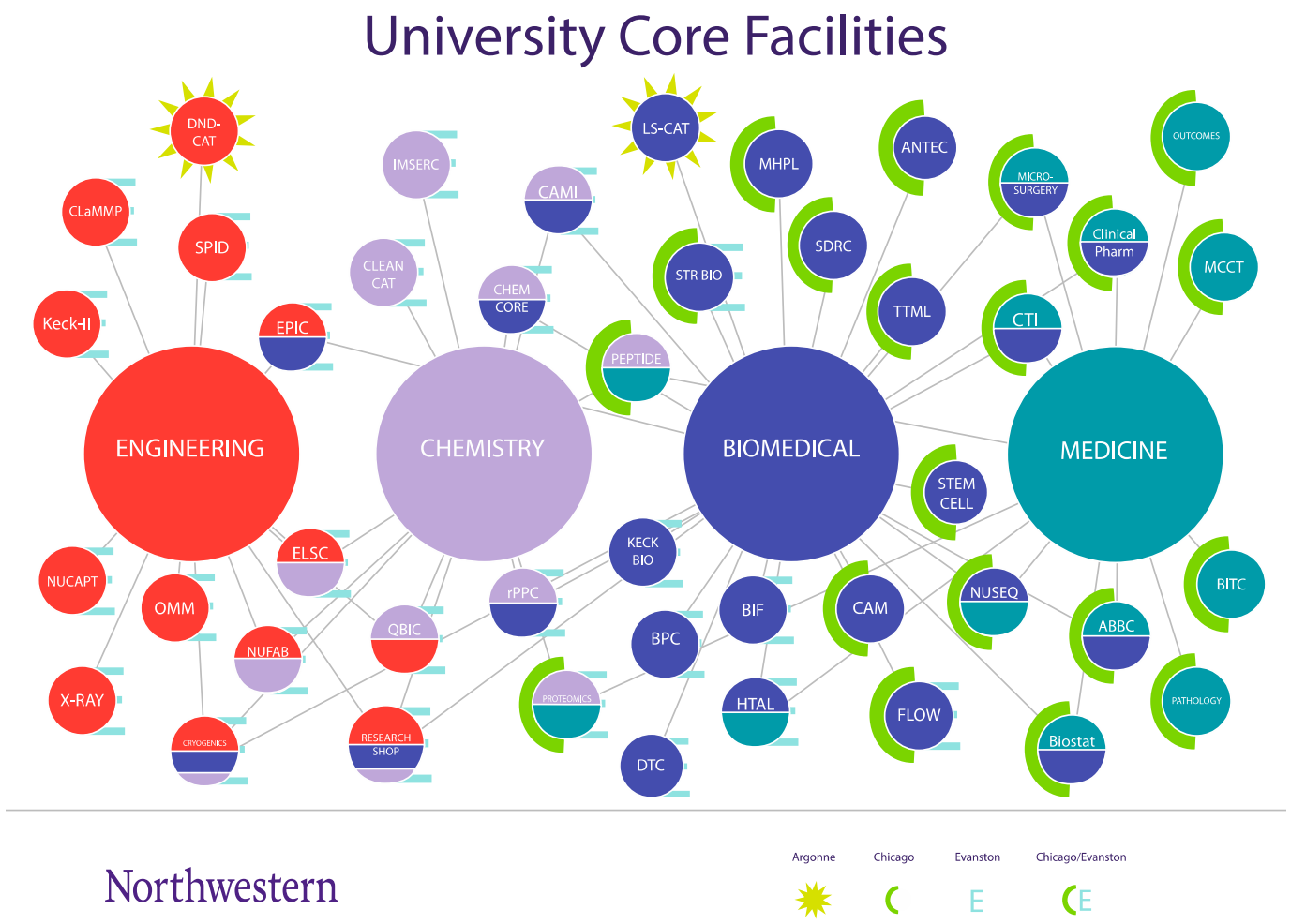

FIGURE 1

Core facilities at Northwestern University are spread across 4 areas of research: engineering, chemistry, biomedical, and medicine (clinical). The facilities on the left side are primarily on the Evanston campus, where there is a flat, egalitarian, organizational structure. The facilities on the right side are primarily on the Chicago campus, where there is a hierarchical, clinically focused organizational structure. Some facilities serve both campuses and must contend with their cultural differences.

share what we have learned regarding each of these pillars in the hope that other institutions may benefit from our experiences. We also provide a glimpse of the future where core personnel are integrated into the academy as valued partners in the research enterprise, thereby fulfilling their long-awaited promise.[1]

THE FOUR PILLARS

Core personnel

Some institutions define a core facility (CF) by its equipment and location, and they assume that users can provide the manpower. In our experience, without technical expertise, there is no core facility. Core personnel are an indispensable part of the value proposition. They provide unique skills, expertise, and experience that foster relationships and build trust and confidence in researchers as they explore new and innovative technologies and applications. They are critical gatekeepers in efforts to address rigor and reproducibility issues plaguing the research enterprise.[7] By ensuring that core directors and staff are leaders in their fields and effective communicators and partners in the research ecosystem, the institution can be confident that faculty are getting the expert advice they need.

At our institution, core directors are predominantly research faculty who are expected to support the research programs of other faculty who are principal investigators (PIs) on grants. Core directors are recruited with strong research backgrounds and domain-specific expertise. Most do not have prior experience running a fee-for-service laboratory. Since core labs are essentially small, nonprofit businesses, we partnered with our business school to develop an executive education course, specifically to provide core

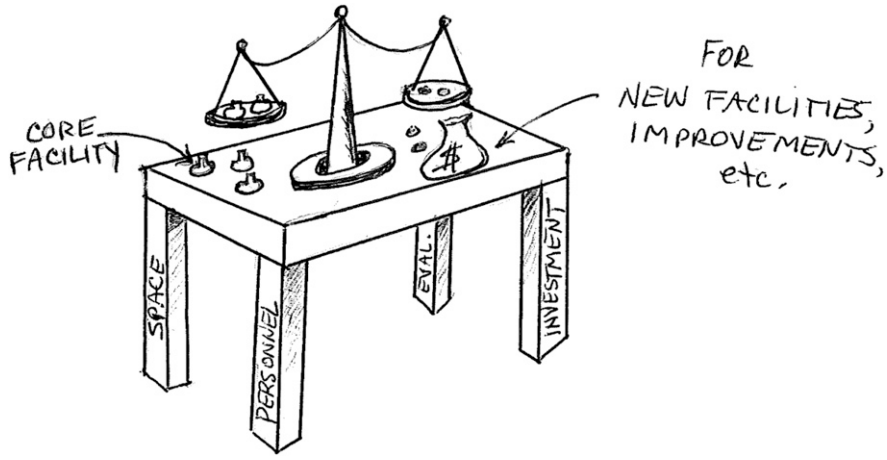

FIGURE 2

The 4 pillars for building a sustainable portfolio of core facilities. Each pillar is essential and necessary to ensure a level foundation on which to make decisions.

directors with an introduction to essential business skills. This 4-d course is now in its fifth year and is available to core staff and administrators overseeing core facilities at any nonprofit institution.[8]

The core staff includes scientists who are hired by the core director and contribute to the day-to-day operation of the facility. The staff provides hands-on technical experience and expertise that support researchers and their experimental needs. As their roles and responsibilities evolve over time, we developed core-specific job families for core personnel (**Table 1**). Exempt staff (core scientists) are outward focused, possess advanced skills and experience, and serve as domain experts for users and their advisors. Nonexempt staff (core technicians) are inward focused, specialize in core laboratory techniques and data collection, and serve as technical experts for users. The creation of job families provides benefits for different stakeholders invested in core facilities by supporting hiring practices and encouraging appropriate promotion and compensation of staff. In short, core-specific job families acknowledge the unique skills and experiences of core staff and their contributions to the research ecosystem.

Another key element of professional development of core directors and staff is encouragement of and the rewarding of contributions to their scientific disciplines. These contributions can occur in a variety of ways, including by developing new techniques, by active participation in regional and national organizations, and by collaborating with PIs inside and outside of the university. An important metric for demonstrating expertise is publication of the primary literature. To facilitate this, we developed publication guidelines for users of core facilities to ensure that research performed in cores is appropriately recognized and cited (Box 1). These guidelines are consistent with international recommendations, provide tangible evidence of the value of core scientists to research projects, and help to advance their careers.[9] Proper recognition of the contribution of core scientists is consistent with the ethical and responsible conduct of research.[10]

Box 1. Publication guidelines for users of core facilities.

The following guidelines are intended to ensure that research performed in core facilities is appropriately recognized and cited. They are compatible with university authorship guidelines, as well as with recommendations of the International Committee of Medical Journal Editors that describe who is an author and what merits authorship in publications (www.icmje.org).

Guideline 1: The following activities should be acknowledged on manuscripts and grants, but they do not by themselves meet the criteria for authorship.

- Core scientist provided routine training or services for the user.
- Core scientist collected data for users that required technical skill but did not involve interpretation of data.
- Core scientist reviewed the manuscript or grant for intellectual content or advised on a revision of it.
- A technical question from a referee about data presented in the manuscript required a response from the core scientist with technical expertise relevant to the project.
- Lab head or PI provided general supervision of the research project without significant intellectual input.
- Lab head or PI provided funding for the project without significant intellectual input.

Guideline 2: If all of the following conditions are met, then a core scientist should be invited to be a coauthor on the manuscript. If a core scientist contributed 1 or more of these, but not all, then it is up to the discretion of the PI whether authorship is warranted.

- Core scientist contributed significantly to the conception or design of the project.

TABLE 1

Job descriptions for nonexempt and exempt staff positions in core facilities

Position	Job Description	Level of Education
Nonexempt staff		
Core Research Technician	Performs required standard operating procedures of the core facility under the direction of a core scientist or manager. This includes the execution associated with established protocols and procedures. Works with core facility staff in using the facility's specialized equipment and services.	BS/BA required.
Core Research Technician Sr.	Performs required standard operating procedures of the core facility under the direction of a core scientist or manager. This includes the execution of research activities associated with established protocols procedures, *as well as modifying them as needed*. Works with core facility staff in using the facility's specialized equipment and services *and is responsible for key duties necessary to maintain daily workflow in the lab*.	BS/BA *and 4 yr of experience in a core facility*.
Core Research Technician Lead	Performs required standard operating procedures of the core facility under the direction of a core scientist or manager. *Provides daily oversight and quality control of research activities. This will involve oversight of the service workflow and core research technicians in the execution and modification of protocols and procedures. Assists in the development and implementation of new core services and other core laboratory and research functions*.	BS/BA *and 6 yr of experience in a core facility*.
Exempt staff		
Core Scientist	Executes research projects under the direction of a sr. core scientist or manager. Provides services and consultation to researchers and investigators in the core to facilitate highly technical and specialized scientific research.	BS/BA *with advanced training in area relevant to the core facility*.
Core Scientist Sr.	Executes research projects independently or under the direction of a core manager. Provides services and consultation to researchers and investigators in the core to facilitate highly technical and specialized scientific research. *May be responsible for oversight of core research technicians and ensures the completion of projects within the core facility. Guides the core in all relevant areas to ensure high quality service for the research community*.	*MS required* with advanced training in area relevant to the core facility; *Ph.D. preferred*.
Core Manager	*Manages all core staff, research projects, and strategic direction of the core facility. Responsible for administrative activities related to core (annual reports,* etc.*). Provides services and consultation to researchers and investigators in the core to facilitate highly technical and specialized scientific research. Leads the core in all relevant areas to ensure high quality service for the research community*.	*Ph.D. required* with advanced training in area relevant to the core facility.

Italic text reflects additional responsibilities with promotions (left to right). BS/BA, Bachelor of Science/Bachelor of Art; MS, Master of Science; Ph.D., doctor of philosophy.

• Core scientist provided "nonroutine" training and services for a user. This includes development of novel procedures for data acquisition or data analyses.

• Core scientist wrote a portion of the manuscript (including Materials and Methods, figure legends, or technical details).

• Core scientist approved and took responsibility for the intellectual content of her/his contribution to the manuscript.

• Core scientist produced a figure for the manuscript using data collected by the core scientist.

Guideline 3: If any of the following conditions are met, then the core scientist should be invited to be a coauthor on the manuscript.

• Core scientist acquired, analyzed, and interpreted data for the project that required unique expertise and skills.

Guideline 4: A core scientist has the discretion to turn down an invitation for authorship if she/he believes that data and interpretation are not consistent with professional standards. The latter may include withdrawal of data or figures from the manuscript generated by the core scientist.

Guideline 5: Disagreement over the type of recognition or withdrawal of data shall be handled initially by the faculty director of the facility. The faculty director will meet with the user, PI, and core scientist to help to resolve the dispute. If she/he is unable to obtain a solution that satisfies all parties, then the research dean of

the appropriate school will resolve the dispute. Failure to abide by the decision of the research dean may result in loss of privileges to use the core facility.

Practical tips for core scientists:

- Post "Publication Guidelines for Users of University Core Facilities" prominently on your website.
- Communicate guidelines to all users, lab heads, and PIs.
- Discuss roles and responsibilities at the beginning of a project to ensure that they are clearly understood. If you believe these go beyond routine services and include substantial intellectual involvement, then make that clear from the start. You may want to create a user agreement that spells out roles and responsibilities and expectations regarding authorship.
- Be clear that payment for services does not substitute for recognition of intellectual contribution to a project.
- Offer to read drafts of manuscripts to ensure the technical aspects are sound before going to press (even when you do not contribute to the work). This builds trust and respect with users, lab heads, and PIs.
- Send reminders to users, lab heads, and PIs to acknowledge you and your facility in grants and publications using data generated in your facility. A good practice is to send this reminder immediately after they have used your facility.

An important human element in the management of core facilities is the contribution of individual faculty oversight committees. Generally composed of a core's major users, the committee represents the interests of the faculty user base and provides strategic guidance to core directors and staff. Faculty research projects strongly influence equipment acquisition, staffing decisions, and service lines created in a core facility. Consequently, cores are created, grown, or closed based on faculty needs and productivity. The federalist approach to decisionmaking at the local level facilitates institutional responsiveness to the needs of the faculty and its research programs. In short, faculty are the ones who set the goals and have the ability to drive institutional investment. This partnership between the faculty and the central administration reduces tension between schools regarding central investments. It also levels the playing field across disciplines and ensures that the institution is investing resources in a strategic, cost-effective manner.

Core space

Core laboratories are unique spaces where researchers are exposed to new ideas, instrumentation, and services and where they can consult with technical experts to advance their research programs. Whereas many of our facilities began within faculty laboratories, we have gradually moved them out of those labs and into their own spaces. This was a necessary step to disentangle each facility from the faculty member's research program and to expand its use for the larger research community. Additionally, the combination of similar equipment in 1 area reduces renovation costs, as individual PI laboratories are unlikely to have specialized infrastructure, such as uninterruptible power, specialized gases, bio/radiation safety infrastructure, and high-speed networking, which are required for advanced instrumentation. This move required institutional coordination and investment to find and renovate space suitable for each facility (Box 2). Over time, growth of some facilities resulted in expansion and modernization, such that they are now admired by faculty and serve as showplaces for visitors and tour groups (**Fig. 3**, for example).

Box 2. Process for addressing space needs of core facilities.

The identification, renovation, and expansion of space for core facilities require careful strategic planning by the CFA in partnership with the CF Advisory Board. At our institution, space is controlled by the Provost's Office but assigned to schools to manage as needed. Management within schools is usually based on negotiated agreements between deans and department chairs. As core laboratories generally arise within departments and centers, their space belongs to them. When use of a core extends significantly beyond the department or center, then it is time to revisit the agreement. This is where the CFA and CF Advisory Board can help to influence how best to use the space. They are in a position to facilitate new agreements and to provide resources for renovations and expansion. This has worked well at our institution where a culture of collaboration and cooperation is valued and reinforced by senior leadership. We have also formalized some agreements into memoranda of understanding to ensure that all parties are agreeable to the terms and conditions, including exit clauses if a core facility no longer remains operational.

Most core laboratories can be segregated into 1 of 2 types with different space requirements: instrument-focused facilities and service-focused facilities, although some have aspects of both. Instrument-focused facilities (*e.g.*, microfabrication, NMR, microscopy, medical imaging) require substantially more space to accommodate instruments, users, trainers, and preparation-processing areas. Some

FIGURE 3

Photographs of core space for the Integrated Molecular Structure Education and Research Center facility in the chemistry department: *a*) NMR suite, *b*) X-ray crystallography suite, *c*) mass spectroscopy suite, and *d*) computer classroom.

facilities have as many as 20 instruments, thus requiring considerable planning and investment to ensure that adjacent workspaces do not interfere with each other. One of the unique business aspects of instrument-focused facilities is that by the addition of more instruments, they can potentially generate more revenue without adding much additional cost (usually just the service contract for the instrument). If current staff has the expertise and capacity to handle the instrument, then appropriate space is the only constraint.

Service-focused facilities (*e.g.*, metabolomics, transgenic and targeted mutagenesis, stem cell, drug discovery), on the other hand, require less space but are more expensive to operate as a result of higher personnel costs. Unlike instrument-focused facilities, users do not typically use instruments in service-focused cores. Instead,

core personnel perform tests on samples provided by users or produce products for users. Results are returned to users as physical items (*e.g.*, peptides, stem cells, transgenic animals) or data files, and further analysis is performed by the user, if she/he has the expertise. If not, then core personnel are available to help with data analysis, figure preparation, and even manuscript writing. It is not unusual for staff to be involved as coauthors on manuscripts (compare with Box 1). Placing some core personnel on grants is encouraged in service-based facilities, providing a rational way to grow staff along with projects.

Regardless of the type of space, construction and renovation of core facilities require institutional planning and investment. This can be facilitated by tapping into existing funding mechanisms for upgrading research infrastructure, as well as through new investments and philanthropy. The main challenge is convincing faculty and central administrators that core facilities are a critical part of the research ecosystem similar to science libraries, animal facilities, high-performance computing facilities, and teaching laboratories. It has been our experience that once the other pillars are in place and managed effectively, then institutional leadership is willing to support the necessary investment in space. Timing is critical for making requests for construction and renovation of cores. Requests that are part of a larger initiative with clear connection to faculty and institutional priorities are much more likely to be successful than stand-alone requests that appear to be for the benefit of an individual PI.

Institutional investment

Core facilities are expensive operations that require considerable institutional investment for both initiating and sustaining operations. Support for core facilities does not necessarily require new investments, however. Universities and research institutes have been investing in advanced instrumentation and shared laboratory space for decades. In addition, there is ongoing support for research administration that can be leveraged to help with oversight and compliance. With careful planning and creative strategies, current allocations or reallocation of existing resources can go a long way toward meeting institutional needs for core facilities. Nevertheless, as described below, new investments and strategies, as well as a sufficient volume of research activity, are needed to build a compliant, sustainable environment.

The leveraging of existing expenditures to support core facilities provides advantages to the faculty and the administration, but this requires the cooperation of both. For example, when faculty are hired (either through recruitment or retention), this often involves support for new equipment for their research. When that equipment is expensive, it comes with a hefty service contract (once the warranty expires) and requires technical expertise to operate. Furthermore, the equipment will likely be outdated in 5–6 yr and will need to be replaced. By placing it in a core facility, these responsibilities are shifted to the core director who is better positioned to handle these issues.

There are other advantages for faculty of leveraging core facilities as part of the hiring process (Box 3). When meetings with core directors are part of the process, faculty members gain firsthand knowledge of the expertise that core personnel provide. This process can improve their confidence that an instrument placed in a core will be managed efficiently and benefit their research program, and it allows them to focus their attention on other resources that they will need in their own laboratories. This approach improves their negotiating power, as their cooperation will benefit the entire institution, and it builds goodwill with colleagues who will associate the recruitment with improved capabilities for them.

Box 3. Leveraging faculty hiring to enhance core facilities.

At our institution, faculty recruitment and retention begin at the department level and require input and support of the relevant dean and central administration (provost and VPR) who control resources for this purpose. Faculty hires in the sciences and engineering fields are an opportunity to leverage these resources to justify the purchase of expensive new equipment and services. Discussions with stakeholders should occur early in the process when the opportunity to balance competing interests needs to be resolved. The presentation of facilities to potential faculty candidates and the discussion of equipment options with core directors allow the recruit to understand better the culture of reliance on cores and assistance that core personnel can provide.

As the VPR contributes resources to faculty hiring, this provides an opportunity for the CFA to become involved. If instruments and services match an existing core facility, then the CFA asks the core director and its advisory board to consider placing them in their facility. Core directors have the option to decline any request if they feel it does not fit with their business plan. On the other hand, if they agree to the request, then the faculty hire has additional negotiating power, as their purchase benefits the entire user community and can result in immediate goodwill from colleagues even before arrival.

Vouchers (internal funds) can be used to incentivize cooperation, and privileged access to instruments and

services can be used to ensure availability. Vouchers are prorated as a fixed percentage of the purchase price (compare with Table 2) and can only be used for that instrument or service. Privileged access is provided through NUcore and allows the donor and the donor's research group preferred access (*e.g.*, scheduling 3 wk out, whereas general users can only schedule 2 wk out). Although these incentives usually satisfy most skeptical faculty, the final decision on where to place new instruments and services is left to the faculty and its specific needs.

Faculty cooperation can be incentivized further through voucher and cost-sharing programs. Vouchers (internal funds) can be used to pay for general use of core facilities as part of start-up and retention funds (**Table 2**). They are also awarded to faculty members who donate a new instrument to a core facility or who write a successful external grant for instrumentation that is placed in a core facility. Institutional cost sharing on instrumentation grants can also be used to incentivize faculty members to write grants for instruments placed in core facilities. By coupling cost sharing with institutional priorities, administrators can leverage existing resources to prioritize targeted research areas.

Besides using existing sources of revenue, institutions will likely need new investments to build a robust, compliant portfolio of core facilities. Examples of new investments include the following: central oversight of core facilities, transaction management software (a centralized ordering system for all shared facilities), a central online database that lists facilities and services (website, search engine), and procedures for handling external customers and corporate partnerships (lab service agreement, memorandums of understanding). Of these, we have found that a centralized transaction management tool is critical, as it provides accurate data usage that is vital for directing limited institutional resources to their highest and best use (Box 4). We have also invested in several internal funding mechanisms to help core facilities keep their equipment and services up to date and useful (**Table 3**). These mechanisms include operating support from schools/departments and centers, instrumentation grants and loans (Box 5), pilot grants for developing new techniques and services, and support for new and growing facilities. Requests are reviewed by a committee of faculty and core directors who recommend funding priorities to central administrators. This cooperative effort facilitates buy-in from faculty and core leadership and promotes a sense of shared responsibility and commitment.

Box 4. NUcore: financial transaction management system for core facilities.

We developed a transaction processing system (NUcore) that permits shared facilities to accept and track orders and to bill for their services. NUcore is an open-source project, although it is programmed by a commercial vendor (Table Xi), contracted specifically to meet the needs of our core facilities. Within Northwestern University, there is no charge for the use of NUcore, and it is available to all research-related organizations on campus. The program is supported by a full-time application support specialist who trains users, solicits feedback, and works with the developer on enhancements.

NUcore is designed to meet the needs of 3 broad user groups:

•Customers

NUcore allows customers to purchase items, request services, and schedule instruments. Users can also log in to check order status, review current and previous charges, and manage their payment sources without the need to contact a core facility. NUcore user accounts and internal payment sources (chartstrings) are universal and may be used in any facility enrolled in NUcore.

TABLE 2

Voucher programs provide financial incentives for faculty who help support core facilities

Program highlights	Beneficiary	Benefits	Administration
Rewards PIs for placing new equipment in CFs (grant, recruitment/retention) Equipment >$100,000 Award = $10,000 maximum (prorated for equipment <$600,000)	PIs, CFs	• No maintenance cost to faculty • Professional staff to maintain equipment • Two-week advanced scheduling • Voucher used to offset user charges for the new instrument	Account owned and managed by CF
Promotes use of services in CFs (recruitment/retention) Award ≥$20,000 No time limit	PIs, CFs	• Unrestricted use in CFs • Relieves funding pressure • Provides central support of CFs	Account owned and managed by department

TABLE 3

List of internal support mechanisms for core facilities

Program	Review process	Frequency	Amount
Operating support (for recharge and nonrecharge activities)	CFA	Annual	Up to $50,000 per facility
Equipment grants (at least 10% cost sharing by departments/schools/centers)	Panel	Biannual	Up to $100,000 per grant
Equipment loans (ReLODE)	Panel	Biannual	Up to $500,000 per loan
Pilot grants for new services	Panel	Ongoing	Up to $15,000 per grant
New and growing facilities	CFA	Annual	Up to $120,000/yr per facility

Funding decision is made by either a review panel of core facility directors and faculty directors or by CFA. The size of awards typically scales with the size of the facility. ReLODE, Research Loan for Old and Duplicative Equipment.

•Core directors and staff

NUcore is specifically designed to reduce the administrative burden on facility managers and directors. Chartstrings are validated to prevent billed items from failing to post in our financial system. Journals are assembled and transmitted electronically, without manual calculation or formatting. Internal and external user credentials are supported. Real-time reporting provides summaries based on common and user-defined parameters, and more granular reports are also available.

•Department/center/university administrators

Specific roles within NUcore allow administrators to manage multiple users and payment sources (*e.g.*, investigators within a department or center). A Cognos datamart also resides over the NUcore database, with direct connections to university reporting and data visualization tools. These interfaces provide advanced reporting across multiple facilities, precluding labor-intensive retrieval and collating of data.

NUcore remains under active development, with updates and new features released every 2–4 wk. New feature requests are prioritized by need—in most cases, features that benefit multiple cores will take precedence over requests that target a single core.

Box 5. Grant and loan programs for capital equipment.

The Office for Research manages and supports 2 complementary programs to refresh and upgrade capital equipment in core facilities: a grant program and a loan program. The grant program is designed to fund smaller-scale upgrades and enhancements to existing instruments or to fund new instruments in which cost is below the minimum of external instrumentation grant programs. The loan program, called ReLODE, is designed to help cores replace or augment more expensive, high-throughput equipment that is often the backbone of our larger core facilities. These programs are highly effective, as they allow users to influence when new instruments are needed, when an old piece of equipment needs to be replaced, or when additional capacity is needed. These programs ensure that cores remain cutting edge in their capabilities, while upgrading "workhorse" equipment that is vital to the research ecosystem.

Core facilities apply to both the Equipment Grant program and the ReLODE program on a biannual basis. Applications are reviewed by a rotating committee of research deans, senior administrators, and facility directors who score each application. For equipment grants, there is a 10% cost-share requirement provided by PIs, centers, and/or department funds, as a measure of buy-in at the local level. Equipment grants are typically limited to $100,000 per instrument. Loans can be up to $500,000 per instrument.

For the loan program, core directors and their advisory committee must sign a form that acknowledges that they agree to be bound by the following terms:

• The facility agrees to purchase the specific equipment. If the facility plans to deviate and purchase equipment that differs in whole or in part from the original request, then the director of core facilities must approve this change in writing before the issuance of a purchase order.

• The facility agrees to repay all funds lent under the ReLODE program in accordance with an accounting

services-approved depreciation schedule and the ReLODE accounting procedure document.

- The facility acknowledges that the Office for Research will pull funds directly from the designated capital account on an annual basis to repay the loan once the newly purchased equipment has been placed into service. The facility further acknowledges that these payments are compulsory, and the home department housing the core facility is responsible for covering any resulting shortage.
- The facility agrees to modify its cost study, incorporating the appropriate equipment depreciation schedule, setting up a new ReLODE capital chart string, and performing the appropriate cost transfers once the equipment has been placed into service. These modifications and annual transfers will remain in effect until the loan has been repaid in full.

Our institution also provides funds to enable core expansion of staffing. Without such support, core directors must assume the financial cost and risk when adding staff. With backstopping (support for costs that are unlikely to be recovered through recharge), the institution subsidizes the cost of new staff during the onboarding period when staff are learning the operations, developing new capabilities, and beginning marketing services to the faculty. We recommend a phased approach involving 50% backstop in yr 1 and 25% in yr 2, although this needs to be calibrated to ensure that there is sufficient time to train and develop new staff and grow new service lines. By limiting support to a finite period of time, the core director is compelled to develop a sustainable business model that grows the facility in alignment with users' needs.

Another factor that impacts the sustainability of core facilities is the requisite volume of use by researchers. Without a sufficient user base, a core facility is unlikely to cover its operating costs, and therefore, it will need substantial institutional support. Survey data indicate that core facilities nationwide cover ~50% of their costs through user fees.[11] For institutions with many facilities, this is not a sustainable model. **Figure 4** illustrates this challenge at our institution and how growth of the user base resulted in a substantial return on investment (ROI) over time. During the first 2 yr shown in the figure, institutional investment represented 81% of all revenue generated across all facilities, and it declined to 54% by fiscal year (FY)2014, as a result of growth in revenue. Starting in FY2015, revenue displayed accelerated growth with minimal change in investment. By FY2017, internal investment remained the same but represented only 36% of total core facility revenue. In short, our portfolio of cores moved from a dynamic, where ~$1 of direct investment was needed to support each dollar of faculty spend, to a dynamic where the same $1 investment supports $3 of faculty spend, a dramatically different calculus. With continued growth in use (revenue) and consistent institutional investment, we are on a path toward financial sustainability.

Before leaving this topic, there is one very important point about leveraging institutional investments to incentivize growth of facilities. Roughly 20% of our institutional investment is targeted to grow capabilities and capacity in existing cores, not just to sustain them. If we had chosen simply to subsidize existing service lines, then we would not have seen increased use (revenue), as there would have been no incentive for cores to grow and no mechanism to create growth. Targeted institutional investment in growth is accomplished through internal investments that create new service lines and encourage cross-core collaboration (consortia) and marketing to external customers to fill excess capacity and investing in cores through faculty recruitment and retentions. Again, a key pillar to building successful core facilities is leveraging both existing and new institutional investments.

Institutional evaluation

Few people enjoy being evaluated; it's human nature. Nevertheless, evaluation is an important means for improvement and accountability, and therefore, it is an essential pillar for building a sustainable portfolio of core facilities. Without this component, the institution lacks critical information it needs for making strategic decisions and investments that advance the research programs of its faculty. For core directors, evaluation provides feedback to improve the effectiveness and value of their services. It also provides an opportunity to reflect on where the facility is in relationship to its discipline and peers and where it would like to be. For core administrators, the evaluation process provides data to ensure excellence in core operations and effectiveness, to maintain a balance across research disciplines, to guide future investment decisions, and to discontinue support for cores that no longer have a positive impact on the research enterprise. Thus, evaluation is important for both individual facilities, as well as the institution. It helps to ensure that facilities are operating in the best interest of the faculty and that core personnel are appropriately rewarded for their contributions.

Effective evaluation requires input from many stakeholders, and therefore, it needs central coordination. At our institution, this coordination is managed by the office of Core Facilities Administration (CFA) within the Office for Research (OR) (**Fig. 5**). This office is responsible for policies/procedures, assessment, investment, and marketing/communications related to core facilities. The day-to-day operations are handled by the director of core facilities who is assisted by 2 staff (financial and administrative assistants) and reports to the associate vice president for research (AVPR). The AVPR is assisted by a core facility advisory board that includes additional AVPRs, associate deans for research, 1 senior core director from each school, and an associate director of the cancer center.

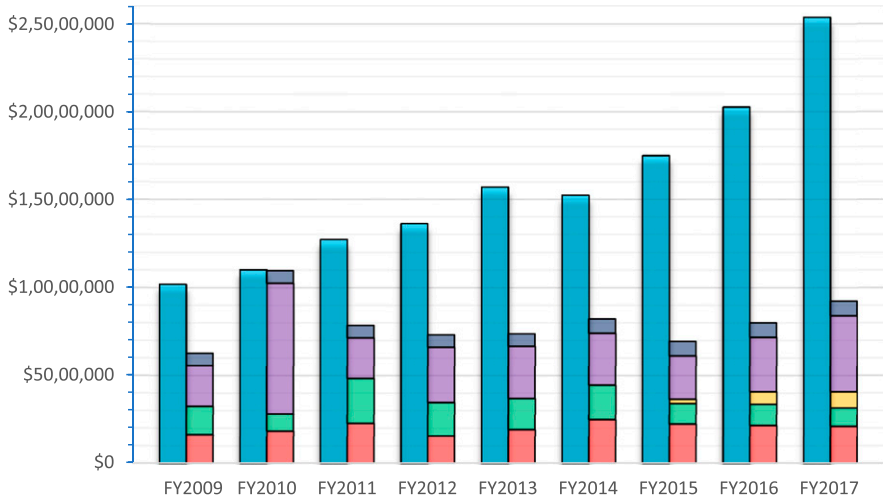

FIGURE 4

Summary of recharge revenue (blue) and institutional investment (other colors) in core facilities over the past 9 yr at Northwestern University.

These stakeholders meet quarterly and provide broad institutional input on operations, evaluation, and investment in core facilities. They are also essential voices for addressing organizational and cultural differences among schools with their unique needs and challenges.

There are various strategies for evaluating the performance of core facilities, and no single approach will work for all institutions. Nonetheless, an important first step is the creation of a set of performance standards and metrics that are appropriate for your institution.[12] At our institution, we have 3 formal processes for evaluating core facilities: annual reports, annual user survey, and program (external) review. These processes are managed centrally and provide invaluable information for administrators and critical feedback for core directors and their advisory committees. Each process is described briefly here to give a flavor of the rigor, benefits, and opportunities for dialog among stakeholders.

We use a "balanced scorecard" approach for annual reports that reflect the priorities of our institution.[12] A key advantage of such an approach is our emphasis on supporting well-rounded cores and not reducing the value proposition of our facilities to profit-loss statements. This approach helps short circuit conversations where central administrators may be perceived by some stakeholders as being driven by financial considerations alone. The report provides information across 8 broad categories: general management, research and technical staff, financial management, customer base and satisfaction, customer publications and grants, educational and outreach activities, communication of services, and self-assessment. Each category is evaluated based on a set of criteria that is established centrally and shared with the leadership of each core facility. Assessment results in a "spider diagram" that yields an annual snapshot of the strengths and weaknesses across these categories (**Fig. 6**). The distribution of ratings across all core facilities suggests that scoring criteria within most categories are well balanced (**Fig. 7**). Each facility receives written feedback on both its operations and finances with the expectation that weaknesses and liabilities will be addressed in the coming year.

An important aspect of the annual report process is the opportunity for the facilities to reflect and respond to the evaluation, as well as to request support to address challenges and opportunities. Core directors and their faculty advisory committees are encouraged to request support for value-added activities (*e.g.*, technique development, grant writing, professional development). Each request is evaluated, prioritized, and supported, depending on available funds. Funding for core facilities is a critical part of the annual review process that rewards core leadership for their efforts and ensures that facilities are

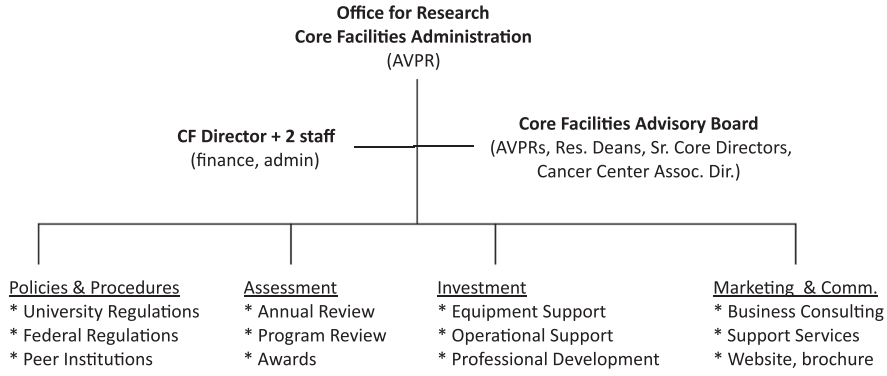

FIGURE 5

Organizational structure and responsibilities of the office of Core Facilities Administration at Northwestern University.

meeting the needs of the faculty. This *quid pro quo* relationship is the foundation for an effective annual review process.

An annual survey of users of core facilities is managed centrally. The survey is sent to all users (internal and external), as well as potential users (new faculty). The survey solicits feedback on their experiences in the previous year and asks if they used comparable services elsewhere. Survey responses provide a wealth of information about the size and breadth of use, effectiveness of existing instruments and services, responsive and expertise of staff, and whether there are unmet needs. It allows the opportunity to identify problems, gauge trends in user behavior, and anticipate new opportunities. Each of these is an important indicator of change in customer behavior and satisfaction that provide critical benchmarks for planning purposes.

Whereas annual reports and user surveys are important assessment tools, they are sometimes insufficient for addressing more fundamental problems in core facilities (*e.g.*, duplicative services, ineffective faculty leadership, disagreement among faculty advisors as to what is needed). When these issues arise, we invite external experts to provide an independent evaluation (program review). External experts are selected in consultation with core directors and their faculty advisory committees to ensure that all parties are vested in the outcome. The review is on-site, lasts 1–2 d, and includes visiting the facility. It involves face-to-face interviews with core leadership and personnel, users, faculty advisors, and central administrators. It results in a written report by the external review team, providing a critical assessment and recommendations. Stakeholders have found this to be an invaluable process for addressing problems and improving facilities, and future support of the facility is contingent on addressing each recommendation in a thoughtful way.

Discussion of assessment would not be complete without mentioning the importance of acknowledging and celebrating the contributions of core facilities to the research ecosystem. We host an annual colloquium and luncheon for all core personnel with invited speakers and topics of interest for their professional development. Core facility awards are given to exemplary facilities based on annual evaluation and other factors, such as national recognition and contributions to scientific breakthroughs. Awards include a plaque, acknowledgment on the CFA website and in OR newsletter, and staff vouchers and bonuses. To date, 15 core facilities have won the award at least once, and 3 have won it >4 times and have received national recognition.

THE ROAD AHEAD

Whereas these 4 pillars are essential for supporting our robust portfolio of core facilities, we recognize that there are additional factors that must be addressed to enable sustainability. A key factor is alignment of their missions with the institution's strategic plan. The research strategic plan at our institution is coordinated through OR. Its goals are established by the vice president for research (VPR) and AVPRs in collaboration with the provost and deans. The FY2019 goals for OR are shown in Box 6, along with how the CFA contributes to them. Note that these contributions are not specific for individual facilities but rather, are aimed at addressing institutional priorities for the research mission. This annual process allows the CFA an opportunity to remind senior leadership of the university of the importance of core facilities in the research ecosystem.

Box 6. FY2019 goals of the Office for Research and contributions of core facilities.

GOAL 1: Promote growth and eminence across the entire university research portfolio, emphasizing the institutional-level research priorities and developing new initiatives within the university and with external partners.

- Maintain leadership and scientific impact of core facilities within the university, as well as regionally and nationally.
- Provide support and professional development opportunities for leadership and staff in core facilities.

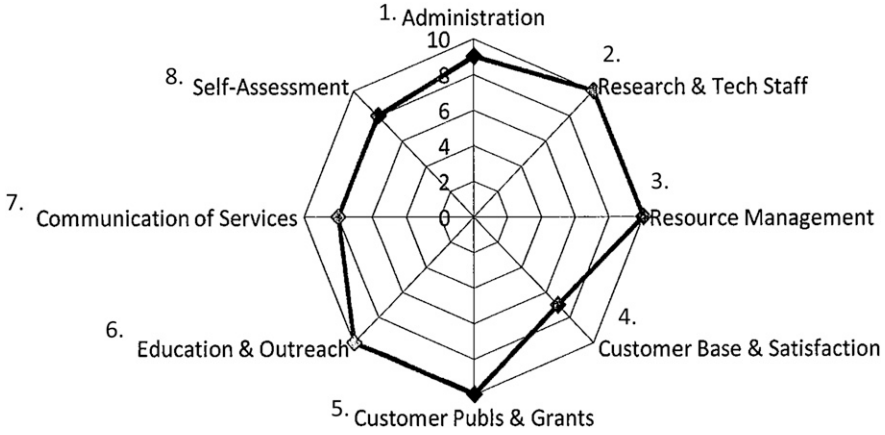

FIGURE 6

Spider diagram depicting scores (0–10) across 8 categories in the annual report of an outstanding core facility. Scores were generated by leadership of the Core Facilities Administration using annual reports and other considerations during the year.

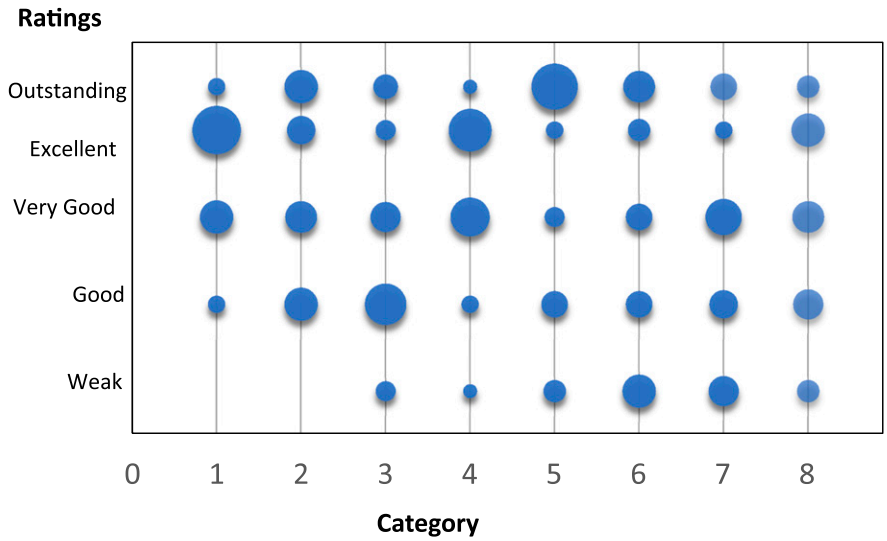

FIGURE 7

Relative rating of all core facilities for each category shown in Fig. 6. The size of each bubble reflects the number of core facilities receiving that rating. Note the fairly uniform distribution of scores within most categories, suggesting that criteria used for scoring are well balanced across core facilities.

GOAL 2: Lead university research planning in partnership with the research community, schools, and central administration.

- Implement recommendations of program review of CFA.
- Facilitate the recruitment and retention of faculty through targeted investments in core facilities.

GOAL 3: Foster a culture of collaborative research at the interface of disciplines by supporting university research institutes and centers and research cores.

- Provide administrative and operational support for core facilities to promote interdisciplinary research and enhance educational and outreach activities.
- Manage OR equipment grant and Northwestern University Clinical and Translational Sciences Institute pilot grant programs to enhance the research infrastructure and promote interdisciplinary research.

GOAL 4: Provide nimble and effective infrastructure and services that meet the needs of the ever-changing overall research enterprise. Advance a data-driven culture for resource planning, process improvement, and metrics of success.

- Support and develop information technology infrastructure for core facilities.
- Coordinate and promote expansion of instrument/electronic shops and microfabrication facilities.

At the national level, Haley and Champagne[13] identified 2 research goals of a modern academic medical center: pursuit of excellence and strategic stewardship. They envisioned these goals as a complementary framework pairing human-oriented research activities (faculty-organizations-teams) with infrastructure-related research activities (space-focus-partnerships). Whereas the former emphasized human capital, the latter emphasized physical capital as essential for planning and prioritizing investments in research programs. They showed how the framework can be used to address strategies for new business models, translational organization structures, and philanthropic agility. Each of these goals and strategies aligns nicely with the pillars we describe for managing core facilities.

Recently, the Federation of American Societies for Experimental Biology (FASEB)[14] identified 4 key areas for improving shared resources: *1*) better internal funding and business operations; *2*) improved discoverability and access; *3*) better planning, coordination, and assessment strategies among stakeholders (including funding agencies); and *4*) enhanced professional development. These recommendations also align with our pillars and even extend them beyond the academy. The authors call for a national conversation among federal agencies, national laboratories, universities, and research institutes to develop a coordinated, national plan for supporting research facilities and infrastructure. We strongly support that recommendation.

Enhanced career development was the subject of another recent FASEB report[15] regarding ways to improve graduate education. One of its recommendations (topic 3) called for improved training in current technologies by recruiting core scientists to help. FASEB noted that core scientists are at the forefront of new technologies and that they foster interdisciplinary science and provide experiential learning opportunities for graduate students. Core scientists are also well positioned to organize and produce educational materials that students and faculty can use. Finally, in addition to training, core facilities offer a new professional career path for graduate students who are interested in advanced technologies and management positions in core facilities and regional and national labs.

These ideas lend support to calls for systemic changes in the way biomedical research programs are structured and

funded.[16–19] These changes include increasing the ratio of permanent staff positions to trainees and the number of core scientists supporting research programs. Both changes capitalize on maintaining in-house expertise and experience and leverage institutional resources to buffer the ups and downs of funding cycles. The long-term costs to sustain these changes will need to be considered in the context of current inefficiencies in graduate education, saturation of the labor market with new Ph.D.s, and loss of talent as a result of poor career opportunities.

The National Research Council[20] noted that the research ecosystem model makes it difficult to assess the cost of any one aspect of the ecosystem in isolation. The key components of the ecosystem are interconnected workforce, dependable resources, and support for basic research across all areas of science. Consequently, one needs a systems-level understanding to calculate the true ROI. To date, no such attempt has been made to calculate an accurate ROI of federal research expenditures. Nevertheless, investment in dependable, cost-effective resources, such as core facilities, will prove a critical component in any such calculation.

In closing, as we look to the future, it is clear that core facilities are playing a significant role in how research universities and institutes address the advanced technology needs of their faculty. It is also clear that cores are part of a growing trend that emphasizes a team-based approach to research. They facilitate collaborations and advance the research mission of universities. They have joined libraries, animal facilities, and computing centers as the physical embodiments of shared resources on campus. Likewise, cores facilities are leading the movement to professionalize staff scientist positions, and core directors are poised to join the academy as full-fledged contributors. Whether as tenure-track or research faculty, core directors are becoming essential partners, instructors, mentors, and innovators of team science. We look forward to the day when they are integrated into the academy as equal partners in the research enterprise and fulfill their long-awaited promise.[1]

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DISCLOSURE

The authors declare no conflicts of interest.

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